DOCUMENT RESUME

ED 312 148 SE 050 918

AUTHOR	Froehlich, Walter
TITLE	The Tracking & Data Relay Satellite System. The New Space Network.
INSTITUTION	National Aeronautics and Space Administration, Washington, D.C.
REPORT NO	NASA-EP-251
PUB DATE	89
NOTE	33p.; Colored photographs may not reproduce well.
AVAILABLE FROM	Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 ($2.75).
PUB TYPE	Reports - Descriptive (141)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Aerospace Technology; *Communications Satellites; *Satellites (Aerospace); Science Materials; Science Programs; *Scientific Research; Space Exploration; *Space Sciences; *Telecommunications
IDENTIFIERS	National Aeronautics and Space Administration; Tracking (Science)

ABSTRACT

This publication describes the giant-capacity space communications installation called the "Tracking and Data Relay Satellite System" (TDRSS). Chapters include: (1) "A New Communications Bridge to Orbit" (illustrating what it is and how it looks); (2) "TDRSS Goes to Work" (describing how it functions); (3) "The Ground Segment" (discussing the system's link with Earth); (4) "Why TDRSS is Needed" (its history and rationale); and (5) "The Space Network Today and Tomorrow." The technical information on the TDRSS, including frequency bands and ground terminal equipment, is appended. (YP)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED312148

The New Space Network

The Tracking & Data Relay Satellite System

NASA

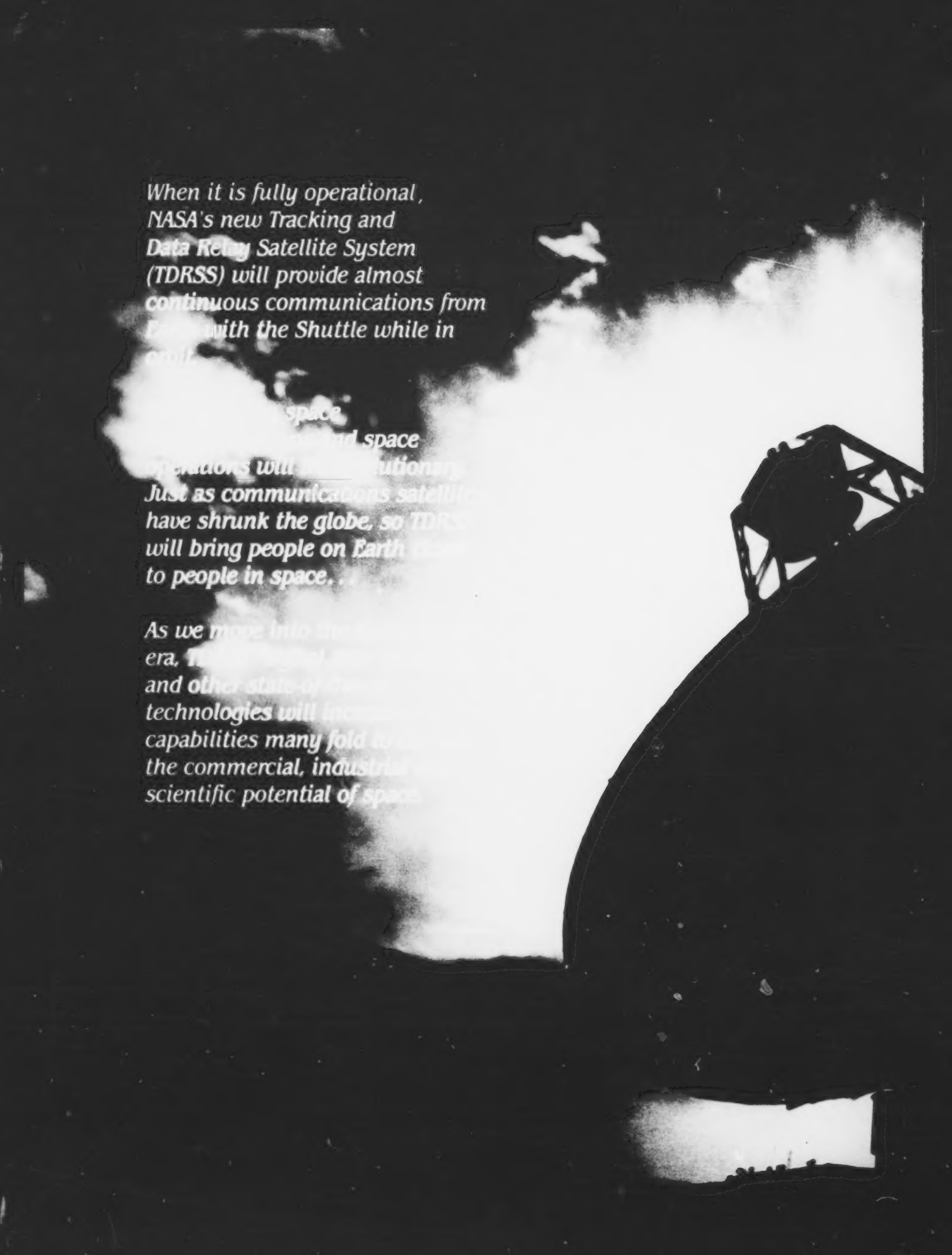
U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

X This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

216 pgs



When it is fully operational, NASA's new Tracking and Data Relay Satellite System (TDRSS) will provide almost continuous communications from [illegible] with the Shuttle while in [illegible]

[illegible] space

[illegible] and space [illegible] operations will [illegible] revolutionary. Just as communications satellites have shrunk the globe, so TDRSS will bring people on Earth [illegible] to people in space.

As we move into the [illegible] era, [illegible] and other state-of-the-art technologies will [illegible] capabilities many fold to [illegible] the commercial, industrial [illegible] scientific potential of space.

The New Space Network

The Tracking & Data Relay Satellite

By Walter Froehlich

NASA

National Aeronautics and Space Administration

EP 251

For sale by the Superintendent of Documents
U.S. Government Printing Office, Washington, D.C. 20402

In the larger context of the U.S. space program, the TDRSS *is the equivalent of a superhighway for voice, video, and data streams.*

Like the multilane parkways, turnpikes, freeways, and beltways, which have changed our lifestyles and our concept of motor transportation in the last 30 years, so the new NASA Space Network *is profoundly altering our perception, as well as the realities of Earth-orbit-Earth*

Contents

Introduction 2

Chapter 1: **A New Communications Bridge To Orbit** 3
What It Is and How It Looks

Chapter 2: **TDRSS Goes To Work** 8
How the New *Space Network* Functions

Chapter 3: **The Ground Segment** 11
The Earth-Based Links

Chapter 4: **Why TDRSS Is Needed** 13
Its History and Rationale

Chapter 5: **The Space Network Today and Tomorrow** 16
Present and Future Uses

Technical Information 22

TDRSS In Action

In November 1983, five men aboard the U.S. Shuttle became the first space crew to enjoy nearly continuous communications with people on the ground while flying in a low Earth orbit.

That mission was the ninth orbital flight for the Shuttle. During it, unprecedented quantities of information were generated by instruments aboard *Spacelab*, the European-built orbital research module then on its first flight in the Shuttle cargo bay.

Much of Spacelab's data was instantaneously transmitted to scientists on Earth. They were able to analyze and respond to these research results while many of these experiments were still underway in orbit.

On that seven-day mission, ***more data was retrieved through space-to-ground communications than on all 39 previous U.S. manned spaceflights combined!***

The nearly continuous two-way voice exchange and record data flows were made possible by the first satellite of NASA's new giant-capacity space communications installation called the "Tracking and Data Relay Satellite System" (TDRSS). This partly completed system augmented the services of the 15 traditional ground-based communications stations. When the three-satellite *TDRSS* is completed with the launching of two more satellites, the *TDRSS* will replace most of these ground stations.

Even though only one of the *TDRSS* satellites is in orbit, the space segment of the *TDRSS*, together with its associated ground facilities, has already significantly influenced U.S. space research and operations.

The system, which is expected to exert momentous impact on U.S. space projects in the immediate future, is explained in this publication.

A SERVANT IN THE SKY is this TDRSS *satellite shown here in orbit awaiting commands and instructions from Earth. The satellite transmits communications to and from research and applications spacecraft.*

TDRSS = Tracking and Data Relay Satellite System

The new *T*racking and *D*ata *R*elay *S*atellite *S*ystem is the key element in NASA's evolving *Space Network*.

In writing, such as in press releases and technical publications, NASA refers to the new system by its abbreviation, "*TDRSS*," and to each component satellite as "TDRS" (with only one "S").

But when talking—in casual conversation as well as at meetings and in formal speeches—NASA officials and others either spell out the letters "T-D-R-S-S" or "T-D-R-S" or pronounce the letters as an acronym that sounds like "Tea Dress."

This pamphlet, like other NASA documents, refers to the new system as the "*TDRSS*." In this pamphlet the system's satellites are called "TDRSS satellites" or simply "satellites." All other Earth-orbiting craft are called "spacecraft" to avoid confusion.

Readers may want to join NASA personnel in saying "Tea Dress" when referring to either the satellites or the system.

Introduction

It seems as if the Earth and nearby orbital regions are moving closer to each other. Voice and data transmissions between the Earth and these regions are multiplying rapidly. NASA is building a new Earth-to-orbit and orbit-to-Earth communications link named "*TDRSS.*" The letters stand for *T*racking and *D*ata *R*elay *S*atellite *S*ystem. When completed, the system, together with its various NASA support elements, will be known simply as the "*Space Network.*" It will substantially increase information exchanges between low-orbiting spacecraft and the ground.

So far only one of the system's three planned communications satellites has been in place in orbit. Nevertheless, *TDRSS* has been keeping the electronic uplink and downlink channels between the Earth and orbiting spacecraft bristling with voices, video, and data. When the system's other two satellites are launched, the completed *Space Network* will represent one of the biggest advances in space communications technology in the 1980s.

So massive is the system's capacity that some knowledgeable observers say nearby orbital regions, in terms of communications, will become nearly as accessible as any continent. In a communications sense these regions will be part of the Earth. Because of this and other advances, the unique resources of space, which were beyond reach by any means until the middle of this century, are gradually becoming readily accessible for very complex scientific and routine commercial and industrial uses.

So vast is the capacity of the new system that it can transmit the contents of an average library from an orbiting spacecraft down to the Earth in a few minutes. At its highest transmission rate, the new system can transfer in a single second the contents of a 20-volume encyclopedia with 1,200 pages in each volume and 2,000 words on each page.

With the *TDRSS* these exchanges can take place almost continuously throughout an orbital mission. Earlier spacecraft communications were limited to a few intermittent minutes on each orbit. To communicate with the Earth, a spacecraft had to be in "view" of a ground station. The *TDRSS* eliminates this restriction.

The large-capacity, near-continuous exchanges achievable with the *TDRSS* are essential for the expanded scientific research and the burgeoning commercial and industrial operations envisioned for space in the late 1980s and early 1990s. Facilities for carrying out these modern research and commercial ventures are already in use, or will be shortly.

Sophisticated instruments carried aboard the bus-size cargo bay of a Shuttle generate huge volumes of data. The data flow becomes even more abundant when the Shuttle carries *Spacelab*. In this compact $1-billion research laboratory built by the European Space Agency (ESA), scientists and technicians can work in orbit on complex projects in a shirt-sleeve environment almost as if they were in their laboratories on Earth.

If this research harvest could not be promptly transmitted to Earth through *TDRSS*, the Shuttle and many of the automated spacecraft of today and tomorrow would need to carry additional, often bulky, data storage equipment. This would take away precious space, weight, and power from research and operational payloads. High-rate data flows are generated nowadays not only by the Shuttle, but also by automated orbiting craft such as modern environmental and Earth resources observation satellites and by the soon-to-be-launched large new Hubble *Space Telescope* that will conduct unprecedented astronomical research.

The instantaneous availability of information from orbit helps scientists on the Earth closely monitor their individual research projects taking place in space. They can adjust instruments by remote control in response to unexpected research results even while the research is underway. They can instantly analyze information with equipment on the Earth and discuss results with colleagues on board the Shuttle while the work in space is in progress. Such interchanges will be essential when manufacturing and other industrial and commercial activities begin on a large scale in the Space Station in the 1990s.

Although the contributions of *TDRSS* are less obviously visible than those of many other space events, *TDRSS* constitutes a valuable national resource. The advantages emerging from it and the benefits that will flow from it are bound to add up in the years ahead to a giant leap for humankind.

IN ORBIT VIEW was captured moments before the ejection of the first TDRSS *satellite from the Shuttle Challenger's cargo bay by a 35mm camera through the Shuttle's aft flight deck window on April 4, 1983. After ejection, the* TDRSS *temporarily floated in orbit. Then its attached "Inertial Upper Stage" (IUS) booster propelled it to a much higher orbit.*

A New Communications Bridge To Orbit

What It Is and How It Looks

Chapter 1

If it could be seen from the Earth's surface, it might look like a giant X far up in the sky. Closer up, it would resemble a windmill. It is a *TDRSS* satellite and, like a windmill, it has four arms or paddles. Two opposing paddles are flat, square solar panels, measuring 3.8 meters (151 inches) on each side. The two other paddles look like upside-down umbrellas. They are parabolic dish antennas with diameters of 4.9 meters (16.3 feet). They are adding new dimensions to space communications.

Holding these paddles in place are booms of extruded beryllium, which form the arms and legs of the X. At the X's center is a box (a six-sided structure or hexagon) to which other antennas of various shapes and sizes are attached. Inside the hexagon are the subsystems that control communications, electric power, satellite attitude, and other essential functions.

Three satellites like this one will make up the orbital segment of NASA's new "*T*racking and *D*ata *R*elay *S*atellite *S*ystem," or "*TDRSS*" for short. It, in turn, is part of the new NASA *Space Network*. This first satellite has been in orbit since April 1983. When launched, the other two satellites will complete the system.

The satellite currently in operation at an altitude of 35,680 kilometers (22,300 miles) above the equator, is too far away to be visible from the Earth's surface. But its presence is felt by the unprecedented services it provides.

The *TDRSS* travels in a "geostationary orbit" (also called geosynchronous orbit), meaning its movements correspond with the Earth's rotation. Thus, if it could be watched from the ground, the satellite would appear to be hanging in almost motion-free suspension above the Earth. Weighing 2½ tons and stretching to 17.4 meters (57 feet) between its most distant rims, it is the largest and heaviest satellite ever launched into a geosynchronous orbit.

The satellite differs from conventional communications satellites in a big way: Our conventional communications satellites connect points on the Earth. They transmit communications between cities, countries, and continents. The *TDRSS* satellite connects the Earth with low-orbiting spacecraft.

When the *TDRSS* is completed with the two other satellites, almost uninterrupted voice and data exchanges will be routinely possible between the Earth and orbiting U.S. Shuttles—all with only one Earth-based communications station.

The system will also allow nearly continuous command and telemetry communications between ground control centers and unmanned, automated research and applications spacecraft orbiting up to several thousand miles above the Earth.

Since the new system's first satellite has been in orbit, it alone (without the help of the remaining Earth stations) has stretched communications between the Earth and the Shuttle from about 15 percent of the time during each orbit to about 50 percent.

During recent Shuttle flights the remaining Earth stations of the 25-year-old Spaceflight Tracking and Data Network (STDN) have been augmenting the first *TDRSS* satellite so that together they have provided the Shuttle with nearly continuous communications service.

Spacecraft traveling to the Moon and to planets are so distant from the Earth that they can "see" about half of the Earth's surface at any time. Thus, even as the Earth rotates, at least one of the three strategically located ground communication stations of NASA's Deep Space Network is within sight of the spacecraft at all times. Communications between the craft and the Earth can be carried on at any desired time or even continuously.

Low-orbiting spacecraft—those at altitudes of up to only a few hundred miles—"see" only a small portion of the Earth's surface at any one time. If no Earth station happens to be in the craft's view, communication with the Earth is not possible. The lower an orbiting spacecraft's altitude, the less communications time is available if the craft depends solely on ground stations for its contacts.

A NEW ERA in communications between Earth and orbit is being ushered in by this first of three satellites, which will make up the space segment of NASA's new Tracking and Data Relay Satellite System (TDRSS). The system, a virtual superhighway for space communications, is opening new opportunities for the uses of space.

All manned spacecraft—except for Apollo flights to the Moon in the late 1960s and early 1970s—have been in such low Earth orbits.

On these flights, including the early Shuttle flights, voice and data transmissions between the spacecraft and Earth were limited, averaging less than 15 minutes on each 90-minute orbit. On a typical orbit, the craft and crew were out of communications reach for some 75 minutes.

The new *Space Network* greatly expands these communications windows. The three *TDRSS* satellites will orbit more than 150 times as high as the Shuttle, which usually remains below 480 kilometers (300 miles), and many times as high as most other low-orbiting U.S. research and applications craft. Looking down from their lofty perch, these new *TDRSS* satellites can accommodate nearly all U.S. low-orbit communications traffic.

Each *TDRSS* satellite is launched from the Shuttle. The satellite's solar panels and antennas are compactly folded as it is stowed in the Shuttle's cargo bay. After the Shuttle attains orbit at an altitude of about 280 kilometers (175 miles), its cargo bay doors open and the satellite is ejected. At launch, each satellite weighs about 2,270 kilograms (5,000 pounds).

After the Shuttle moves a safe distance away, the satellite's attached booster rocket, known as an "Inertial Upper Stage" (IUS), ignites and lifts the satellite to its geosynchronous orbit. There, the satellite detaches itself from its booster and then the solar panels and antennas unfold.

When unfolded, the satellite measures 17.4 meters (57 feet) from the outer edge of one solar panel to the outer edge of the other, and 14 meters (46 feet) from the outermost edge of one dish antenna to the outermost edge of the other. The satellite is allowed to drift—assisted by its attitude control thrusters—to the position assigned to it in orbit.

Maneuvering a satellite into its proper orbital slot requires careful and close coordination between ground-based tracking systems and the satellite control center. These facilities monitor the satellite's position and movements and send up radio commands to activate the satellite's propulsion system until the satellite is properly aligned in the desired position and attitude.

The new *Space Network*'s first satellite—the "East Satellite"—has been on station since 1983 above a point at the equator near the city of Fortaleza on the northeast coast of Brazil (41 degrees west longitude).

The system's second satellite—the "West Satellite"—is to be positioned above the equator north of the Phoenix Islands in the mid-Pacific Ocean (171 degrees west longitude).

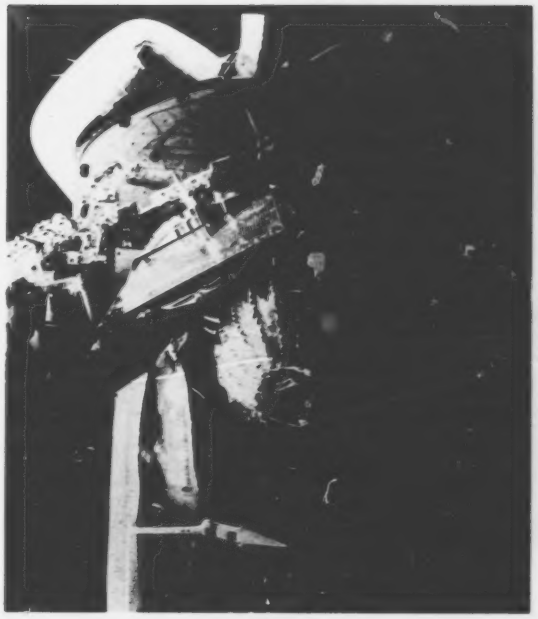
TDRSS-EYE VIEW.
At its altitude of 35,680 kilometers (22,300 miles) above the equator, the TDRSS satellite can "see" half of the Earth and thus can keep in communications contact with low-orbiting spacecraft for at least half of the time during each of their orbits. The new space communications system requires only one ground terminal in contrast to the earlier systems.

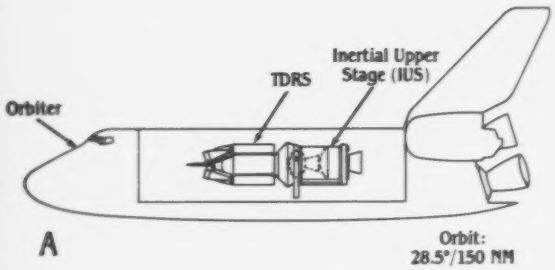
The third satellite is to be used as a spare, and will be positioned between the others. Its precise location has not yet been selected, but it will be above the equator, probably close to the border of northwestern Brazil and Venezuela. There it will be kept largely inactive as a backup, but ready to be moved in the place of either of the two active satellites if one of these should malfunction.

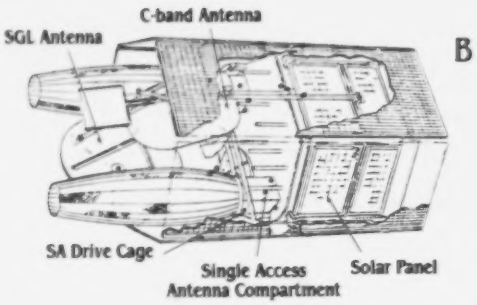
The three *TDRSS* satellites make up the space segment of the new *Space Network*. Together with its ground-based segments, the *Network* will be able to support the complex advanced scientific, commercial, and industrial projects planned in low Earth orbits in this decade and through the 1990s.

In the larger context of the U.S. space program, the new *Space Network* is the equivalent of a superhighway for voice, video, and data streams. Like the multilane parkways, turnpikes, freeways, and beltways, which have changed our lifestyles and our concept of motor transportation in the last 30 years, so the new NASA *Space Network* is profoundly altering our perception, as well as the realities, of Earth-orbit communications.

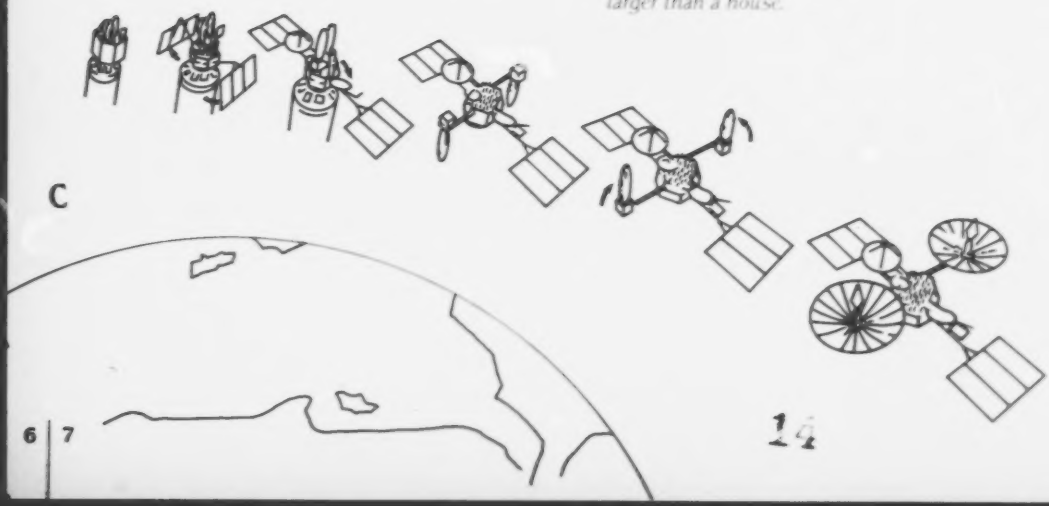
Most treasures from space have so far been in the form of information and observations. These are leading to knowledge and understanding perhaps more precious than material returns. The three *TDRSS* satellites and their associated facilities substantially increase the quantities of information and observations that can be transmitted to the Earth.







READY FOR LAUNCH a folded TDRSS satellite is a compact package tucked neatly into the cargo bay of the Shuttle (illustrations A and B). After having been injected into its 35,680-kilometer-high orbit (22,300 miles) the satellite unfolds (illustration C) until its antennas and solar panels stretch to dimensions that make it larger than a house.



Chapter 2

Emergency! Odd digits are appearing on a monitor screen. Unintelligible responses are returning from orbit. The on-board memory is failing on one of our most valuable automated scientific research spacecraft. There is danger we may lose the services of this still young space machine worth tens of millions of dollars.

Using the lone operating TDRSS *satellite, controllers extend their allotted communications time with the ailing spacecraft from 20 minutes to 50 minutes during each of the craft's next four orbits.*

In these 200 minutes, the controllers "dump" (recall to Earth) the contents of the craft's memory and analyze them. They then reload the craft's memory and send along the necessary commands to restore the craft to its normal working condition.

"In its two years of operations (the system's first satellite) has achieved an outstanding record of success.... If one considers the Shuttle and Spacelab support [TDRSS has given] and the on-going support of the unmanned spacecraft, even with only one satellite in the space segment, TDRSS has already validated the operational concepts which led to the initial approval of the program."

Robert O. Aller
NASA Associate Administrator
For Space Tracking & Data Systems
(in speech at 36th Meeting of the
International Astronautical Federation,
October 1985, Stockholm)

DEPLOYMENT OF TDRSS satellite depicted in this drawing shows the satellite after its ejection from the Shuttle's cargo bay. The satellite floats in a parking orbit awaiting ignition of its attached booster rocket for lifting it to its required much higher orbit.

In earlier days, before the *TDRSS* satellite was available, controllers had to analyze spacecraft problems and make repairs by remote control during the few intermittent minutes a spacecraft was within communications range of an Earth station.

The emergency described above and its happy ending, which occurred in November 1985, is one of scores of events which have dramatically illustrated the virtues of the new system since its first satellite began service in 1983. The expanded communications times with *TDRSS* have been credited with making possible adjustments and repairs that have kept several faltering spacecraft in operation.

The new satellite—like its two companions which are to join it—is a "repeater." It neither processes nor alters any communications. It is almost like an echo in the sky. It functions like a mirror, or more accurately, like a switchboard in orbit:

- Its "uplink" or "forward" channels receive transmissions from the ground, amplify them, and retransmit them on another frequency to the orbiting spacecraft to which they are addressed.
- In its "downlink" or "return" mode, the new satellite receives transmissions from a spacecraft, amplifies them, and retransmits them to the ground terminal.

Engineers say the new satellites work in a "bent-pipe mode." Communications pass through these satellites much the way fluids flow through an **L**-shaped or **V**-shaped pipe. Signals are not changed, merely redirected.

All communications between a *TDRSS* satellite from or to the Earth pass through the satellite's 2-meter-diameter (6.7-foot) dish antenna. That antenna, near the satellite's hexagon central structure, is dedicated to Earth-to-space and space-to-Earth traffic.

When the satellite receives transmissions from the ground terminal, it instantaneously retransmits them through one of its two parabolic "inverted umbrella" antennas or through the array of 30 cylindrical antenna elements mounted on the satellite's hexagon central structure. The parabolic antennas and the array elements are used exclusively for communications with orbiting spacecraft.

The two parabolic "inverted umbrella" antennas are called "single access antennas" because each of them can be used by only one spacecraft at a time for sending or receiving transmissions. The 30 cylindrical antenna elements on the hexagon can handle communications traffic to and from up to 20 spacecraft simultaneously. They are called "multiple access antennas."

The single access antennas are steerable. They can be mechanically turned by remote control to face toward a spacecraft and receive or transmit at very high rates. At their best performance, these antennas can receive or transmit in each second up to 300 megabits (300 million electrical impulses designating ones [1] or zeroes [0], from which letters and numerals or images can be derived).

It is this high rate of data flow through these high-gain antennas that makes possible the system's capacity of transmitting the equivalent of the contents of a multiple-volume encyclopedia each second. These antennas are especially designed for use by spacecraft that generate and transmit large quantities of data to Earth.

COMMUNICATIONS at high speeds can take place between the Shuttle (shown in its typical low-altitude orbit) and Earth through the "single-access" antennas of the TDRSS satellites. At the highest transmission rate, each umbrella-like antenna can transfer the equivalent of a small library, word for word and page by page, between a spacecraft and the Earth station within a few minutes.

In contrast, the array antennas, while able to accommodate up to 20 spacecraft simultaneously, can receive or transmit at only much slower rates—up to 50 kilobits a second. That is still a large quantity of transmissions, the equivalent of about 20 typewritten pages of 200 words each per second. Yet, even when the second active *TDRSS* satellite goes into operation, the combined capacity of the multiple access system will remain at 20 simultaneous transmissions.

Thus, the limit for the entire *TDRSS* system using two active satellites will be four simultaneous high-data transmissions and 20 at the lower data rates.

Each *TDRSS* satellite is made up of three modules:

(1) The EQUIPMENT MODULE, also called the "Spacecraft Module," is in the lower part of the satellite's core hexagon. This module encompasses subsystems that control the thrusters to keep the satellite on station and in the desired attitude. The module also houses equipment that stores and manages the power supply, and the machinery that operates telemetry and tracking equipment.

(2) The COMMUNICATIONS PAYLOAD MODULE in the upper part of the hexagon (just below the multiple access antenna elements) contains electronic equipment that regulates the flow of transmissions between the various antennas and other communications functions. This module's electronic communications equipment forms, in a way, the "elbow" of the "bent pipe."

(3) The ANTENNA MODULE consists of a platform holding various antennas including the 30 helices of the multiple access phased array system.

When the *Space Network* is complete, it will provide global coverage except for one remaining gap. Even the strategic placement of two satellites cannot give 100-percent coverage for low-orbit spacecraft.

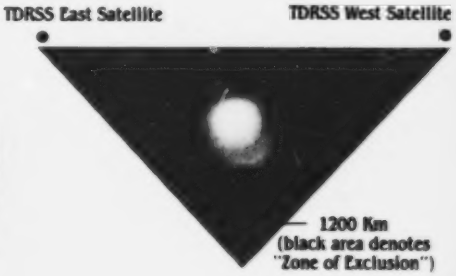
That gap exists on the side of the Earth opposite the midpoint between the two satellites. Thus, a region over the Indian Ocean stretching from the Earth's surface up to an altitude of 1,200 kilometers (750 miles) is not within view of either satellite. The curvature of the Earth blocks the view. Spacecraft passing through that zone at altitudes of less than 750 miles will not be able to have communications contact via the *Space Network*.

That relatively narrow "Zone of Exclusion" (ZOE) stretches for slightly less than 350 kilometers (200 miles) on the Earth's surface, but shrinks with increasing altitude. Spacecraft in orbits above 1,200 kilometers are unaffected. *TDRSS* provides them with 100-percent around-the-Earth coverage.

The satellites are only part of the *Space Network*. Its other parts are on the Earth. The *TDRSS* ground station and a variety of other ground facilities also are essential for the voice, command, telemetry, television, and data transmissions and tracking services the *Space Network* is designed to provide.

POSITIONS OF the West and East TDRSS satellites are shown on this map in relation to their New Mexico Ground Terminal.

ZONE OF EXCLUSION is depicted by the dark triangular area on the bottom of the globe indicating region not visible from the TDRSS satellites. That relatively small region is the only place at which low-orbiting spacecraft are out of contact with the new space-based communications system. Spacecraft at altitude of 1,200 kilometers (750 miles) or higher have 100-percent coverage through TDRSS.



17

The Ground Segment

The Earth-Based Links

Chapter 3

The *Space Network*'s link with the Earth is the *TDRSS* White Sands Ground Terminal in New Mexico.

Three giant 18.3-meter-diameter (60-foot) dish antennas reach skyward above a desert plain surrounded by mountains. Several smaller antennas are nearby. So are office and equipment buildings.

Here, in this southwestern state, not far from the U.S. border with Mexico, is the hub of the *Space Network*. The White Sands antennas connect the Earth with the *TDRSS* satellites and through them with the growing community of low-orbiting U.S. spacecraft.

The White Sands Ground Terminal acts like the neck of an hourglass or the tube of a funnel. All transmissions from Earth to the *TDRSS* satellites, or from them to Earth, pass through this station.

Since the *Space Network* will eventually serve nearly all low-orbiting U.S. spacecraft, virtually all U.S. communications traffic between the Earth and nearby space—uplink and downlink—will ultimately pass through the White Sands facility.

The large dishes, designated the North, Central, and South antennas, dispatch transmissions to, and receive transmissions from, the satellites. These dishes are the links between the *TDRSS* satellites and the Earth.

Smaller antennas are used for related functions such as testing spacecraft for their compatibility with the *Network* before their launch. These antennas can simulate transmissions to and from a spacecraft while it is still on the ground.

Through the *TDRSS* satellites pass commands to spacecraft to adjust their positions by firing a thruster, to turn a camera or heater or other on-board equipment on or off, to start or stop observations, and to begin or stop transmissions to the Earth. Also passing through the uplinks are instructions or data for storage in a spacecraft's memory. Later the spacecraft can draw on this information for guidance in automated operations.

Downlink traffic through the *TDRSS* satellites consists primarily of telemetry data. Spacecraft report their current physical condition such as their operating temperature, fuel levels, and power supply and the results of their observations or experiments. Shuttle crews use *TDRSS* voice channels for conversations with Mission Control.

The New Mexico site was chosen as the *TDRSS* ground focus partly because the region's dry climate and sparse rainfall is favorable for the heavy electronic traffic. Heavy rains and even high humidity can seriously interfere with communications at the system's frequencies.

This could become particularly detrimental because the two active satellites are not directly overhead, but on near opposite horizons from the White Sands Terminal. Although both satellites are continuously in the line of sight of the White Sands Ground Terminal for uninterrupted communications contact, their lines of sight to the station pass through the atmosphere over a long diagonal route. Heavy atmospheric moisture could cause severe absorption and degradation of transmissions.

GROUND TERMINAL. Nestled on a desert plain surrounded by mountains, is the TDRSS *White Sands Ground Terminal in New Mexico in the southwestern United States. Since nearly all communications to and from low-orbiting U.S. spacecraft, including Shuttle communications, will in the future be passing through the* TDRSS *satellites, this terminal will be the hub for contact between the Earth and near-Earth space for the United States.*

The New Mexico station is responsible for operating the antennas and the equipment for processing the radio-frequency signals and for maintaining the quality of the *Network*'s space services. But the White Sands Ground Terminal is only a part of the *Network*'s ground segment.

The *Network* Control Center is at the Goddard Space Flight Center in Greenbelt, Maryland, a few miles from Washington, D.C. Here, at the main control room, technicians work at 19 dual monitor consoles 24 hours a day, seven days a week. Ten other consoles are nearby for supervisory personnel, for service scheduling, and for emergency backup. The Center monitors, manages, controls, and coordinates the *Network*.

Technicians here draw up the schedules for the times and duration the *TDRSS* satellites are to be used for transmissions to and from any particular spacecraft. Control Center personnel also schedule the routing for transmissions received from each spacecraft. These transmissions are distributed to NASA project operations control centers and to each experiment's data analysis laboratory and through them to the individual researchers. These project operations control centers analyze the incoming telemetry and often respond with requests that the *Network* Control Center forward commands to adjust a craft and its equipment.

The distribution of spacecraft telemetry is made through the global NASA Communications Network (NASCOM), which also has its headquarters at the Goddard Center. NASCOM uses land lines, ocean cables, microwave links, and commercial satellites as appropriate for each particular communication.

Typically, telemetry from a low-orbiting spacecraft may follow a zigzag route to its ultimate destination into the hands of researchers. Transmissions from a low-orbiting spacecraft are first directed upward to a *TDRSS* satellite, which instantaneously relays them down to the White Sands Ground Terminal. From there the transmissions may be sent up to a commercial communications satellite, which relays them to the Goddard Space Flight Center. There data is processed into forms useful for research and applications.

From the Goddard Center the data may move up again to another commercial satellite that will relay it to the appropriate data handling center where it will be analyzed by researchers and archived for future recall. Less urgent transmissions are recorded on magnetic tape and mailed.

One kind of receiving location is called a "Payload Operations Control Center" (POCC), and it is at these POCCs where researchers obtain the instantaneous results from their research equipment aboard a spacecraft. This allows researchers to order adjustments to on-board instruments as indicated by the early feedback so as to obtain the best scientific results from their experiments.

Most detailed analysis is done at the laboratories of the researchers, and some of the POCCs are located at their home laboratories on university campuses and in research centers.

THREE ANTENNAS, each 18.3 meters (60 feet) in diameter, at White Sands, are the main communications links between the Earth and the TDRSS satellites. The satellites, in turn, will be the main communications links for nearly all low-orbiting U.S. spacecraft.

For example, the POCC for a research spacecraft known as the Solar Mesosphere Explorer is located at the University of Colorado, Boulder, Colorado. For Shuttle flights, the Mission Control Center is at the Johnson Space Center in Houston, Texas. For Spacelab, dual POCCs are at the Marshall Space Flight Center, Huntsville, Alabama, and at a European Space Agency facility in West Germany. POCCs for several spacecraft are located at the Goddard Space Flight Center, Greenbelt, Maryland.

Also received at the Goddard Center is information gathered by special instruments on Earth from which the precise location of the *TDRSS* satellites can be determined. These instruments—a Bilateration (monitoring from two sides) Ranging Transponder System—obtain ranging data which are transmitted to the Goddard Center's Flight Dynamics Facility. There, powerful computers calculate the precise location of each *TDRSS* satellite.

While a spacecraft communicates with a *TDRSS* satellite, the *TDRSS* simultaneously gathers ranging information on that spacecraft and transmits this information to the ground. The same Goddard computers use this data to calculate the precise position of each of the various spacecraft.

Thus, the *Space Network* involves substantial installations on the ground as well as in space.

© National Geographic Society
Painting by Davis Meltzer

COMPLEX ZIGZAGGING communications links of NASA's modern TDRSS *are depicted in this diagram. The sequences demonstrate the central role of the* TDRSS *satellites. Shown here is a Landsat Earth resources observation craft (big craft in center) establishing its position through references to four other craft (dotted lines), then scanning the Earth (depicted here as a beam on large arrow on Earth). The craft then transmits its observations to the* TDRSS *(top center). The* TDRSS *also receives transmissions from the Shuttle and the Space Telescope (lower and middle right). The* TDRSS *satellite returns all of these transmissions to the White Sands Ground Terminal in New Mexico (bottom left antenna) which, in turn, sends the transmissions up to a commercial satellite (upper left corner). That satellite returns the transmissions to the Goddard Space Flight Center (antenna at bottom right). There, transmissions are processed and distributed to researchers and other users of the information.*

Why TDRSS *Is Needed*

Its Rationale and History

Chapter 4

Staccato beeps and wavering whining tones were the first sounds the public came to know from satellites in space.

The sounds, which were often replayed on radio newscasts in the late 1950s, were part of the telemetry through which these satellites made known their presence, their orbital paths, and the findings of their scientific observation instruments.

Much has changed in space operations since then, but communication is still essential today. When the beeps or whines stop and the telemetry ceases—when a spacecraft can no longer communicate—it becomes worthless no matter how well its remaining instruments work. If it cannot transmit its findings, a satellite instantly turns into "space junk," a useless artifact racing purposely through the sky.

The first U.S. spacecraft—Explorer I—left its imprint on history not merely by its spectacular launch on January 31, 1958, but even more so by the scientific observations it communicated. Its transmissions from orbit led to the important discovery of previously unknown radiation zones surrounding the Earth. These zones were named the "Van Allen Belts" after the University of Iowa physicist who had designed the experiments on board Explorer I.

In those early days of the space age, communication with orbiting craft was made possible by strategically placed Earth stations. They were scattered across continents beneath the typical orbital paths of early spacecraft.

The construction, maintenance, repair, and operation of these Earth stations required negotiations with the governments of the various nations on whose territories these staions were built. Entry permission had to be obtained for U.S. personnel and equipment. Access could not always be readily gained even though many of these countries took great pride and satisfaction in the role the stations gave them in early space explorations.

Although these stations served the early U.S. space program well, they demonstrated severe disadvantages. Spacecraft in orbits of up to only a few hundred kilometers above the Earth's surface could communicate with these stations only sporadically.

Communications was possible only from the time a spacecraft rose above a station's horizon until it disappeared below the opposite horizon. Such overhead passes were typically only a few minutes long, and on most orbits a craft rarely passed more than a few stations. All U.S. manned spacecraft, except flights to the Moon, were in such low orbits.

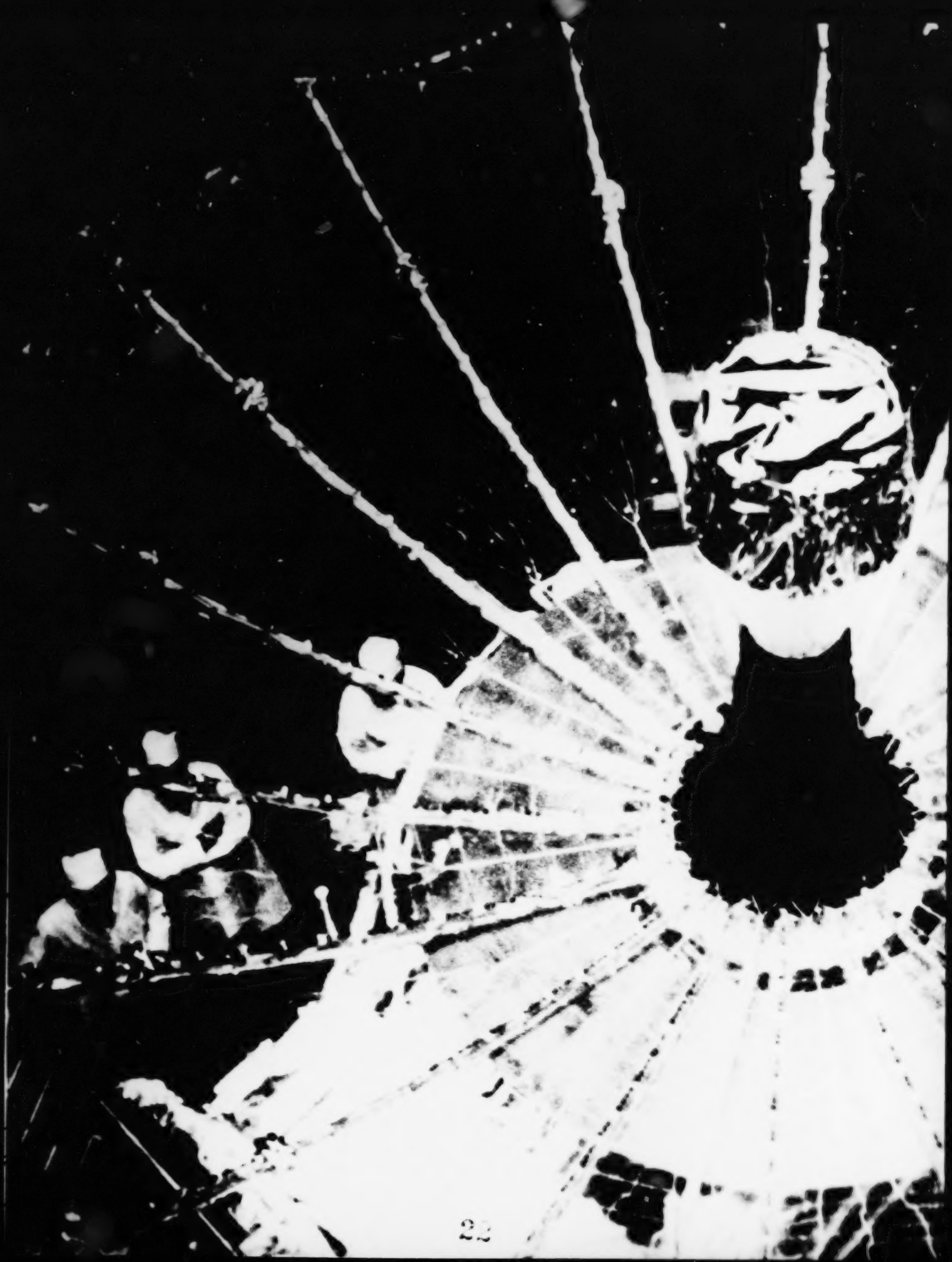
These spacecraft, at altitudes of up to only a few hundred kilometers, were typically able to communicate with the ground no more than about 15 percent of the time. For 85 percent of each orbit, they were beyond any communication contact.

This was true even though the ground network was supplemented during many of the flights by tracking ships and communications aircraft to provide coverage at locations where ground stations were unavailable or impractical.

In the U.S. Mercury, Gemini, Apollo, and Skylab programs of the 1960s and 1970s and the first several Shuttle flights in the 1980s, the combined communication time with all Earth stations averaged less than 15 minutes during each 90-minute orbit. Unmanned, automated spacecraft in low orbits fared no better, and some ground stations could monitor only two spacecraft at a time.

By the early 1970s U.S. space planners knew that the network of Earth stations would be inadequate for the ambitious projects of the Shuttle era. A fleet of Space Shuttles, each with a bus-sized cargo bay, then on the drawing boards, would carry into space a series of research instruments equal to a small research center. With crews of up to eight persons working in shifts around the clock throughout a Shuttle flight of up to eight days or longer, voice and data communications would take on giant dimensions.

LIKE A GIANT BLOSSOM, the unfolded 4.9-meter diameter (16.3-foot) antenna of a TDRSS satellite makes a startling sight during ground tests.



Similarly, unmanned, automated science and applications spacecraft were growing in size and weight. They carried more instruments, and many of these instruments were more complex than those carried by their predecessors. Their communications needs would multiply many times.

For example, environmental and resources observation satellites were about to add sophisticated new equipment. The Hubble Space Telescope, which is expected to provide unprecedented astronomical observations, will call for complex transmissions for remote control of its instruments and, in turn, should yield voluminous observational data for conveyance to the Earth.

Many more ground stations would be needed. The capacity of the existing stations would have to be significantly enhanced. Studies showed that even with these costly improvements the network of ground stations would still fall far short of the nearly continuous coverage desired for the Shuttle and other spacecraft at low orbital altitudes.

Furthermore, quick retrieval of telemetry data collected at the ground stations scattered around the world would be needed. These data would have to be sent to central collection points at high-volume transmission rates. Costs of such a service would be very high.

Preliminary studies of a possible space-based tracking and data relay system had been underway within NASA for several years. In one experiment the ATS-6 Earth synchronous spacecraft successfully relayed commands from Earth to a Nimbus weather and environmental spacecraft. ATS-6 then gathered data transmissions from the Nimbus and relayed them to Earth.

These experiments demonstrated that a space-based system was feasible with available technologies. The envisioned system could meet all expected new requirements for communications, data acquisition, and tracking. Its projected costs, when amortized over 10 years, compared favorably with the estimated expenses of upgrading and operating the ground station system. Moreover, only one ground

ANTENNAS and solar panels snugly folded, a TDRSS satellite is being readied for mating to its booster rocket.

THRUSTER ENGINES, like this one-pound model, are used to keep TDRSS satellites from drifting from the precise positions they must retain for their work. This thruster was also used to move the first TDRSS satellite to its proper orbit after a malfunction in its booster rocket had inserted it into an unsatisfactory orbit.

terminal would be needed for global coverage with obvious savings in construction and maintenance, and administrative costs.

In its financial analysis, NASA found that it would be advantageous to lease the new system rather than to own it. This would allow NASA to use its current budget resources for space research and Shuttle development rather than tying up large capital expenditures for the new system. NASA would then pay for the system as it was being used over 10 years through annual service fees.

Thus, in December 1976, NASA contracted with the Space Communications Company (SPACECOM), now headquartered at Gaithersburg, Maryland, to develop the system and lease it to NASA. Subcontractors were the Harris Government Communications System Division, Melbourne, Florida, and TRW Defense & Space Systems Group, Redondo Beach, California. Harris furnished the White Sands Ground Terminal equipment and the single access antennas. TRW designed, built, and tested the three satellites and integrated the ground terminal equipment. Funds were borrowed from the U.S. Treasury Department's Federal Financing Bank.

The first satellite was launched on April 4, 1983, in what was then the sixth orbital flight of a Shuttle. A malfunction in the Inertial Upper Stage, to which the satellite was attached, placed the satellite into an unsatisfactory egg-shaped orbit in which its communications coverage was very limited. Specialists from the Goddard Center, TRW, and SPACECOM developed plans to correct the orbit by commanding the satellite to fire its thrusters in a carefully times series of bursts. The maneuvers were successful, and on June 29, 1983, the satellite reached its intended circular synchronous orbit.

While awaiting the completion of the *TDRSS* with the launches of the system's other two satellites, the 25-year-old network of ground stations has continued to serve, augmenting the single *TDRSS* satellite.

When the new system is complete, only a few ground stations will be retained. Among them will be the stations at Merritt Island, Florida, and those in Bermuda. They are used by the Shuttle during its launches and landings when the flight position of the Shuttle antennas makes communication through the *TDRSS* satellites impossible. Also to be retained are stations needed to service spacecraft whose orbits are incompatible with the *TDRSS*.

When the *Space Network* begins full operations NASA will be prepared to give low-orbiting spacecraft the communications support needed for the exciting space projects planned for the remaining years of this century.

TDRSS SATELLITE perched on its booster rocket is ready for stowage into the Shuttle cargo bay for launch. The booster, called an Inertial Upper Stage (IUS), lifts the TDRSS satellite from the Shuttle's low orbit to the high orbit the TDRSS requires. Note worker at lower left for comparison with IUS-satellite size.

2a

The Space Network Today and Tomorrow

Present and Future Uses

Chapter 5

The regions above the Earth's dense layer of atmosphere, which were beyond reach by any means until the middle of this century, are gradually becoming sites for routine scientific research and commercial and industrial operations.

NASA's fleet of Space Shuttles has made frequent flights of up to eight days or longer into these regions with up to eight-member crews. Dozens of complex automated craft in low-altitude orbits are also showing that these areas offer unique, extremely useful attributes. These once forbidding regions are turning into familiar, beneficial zones.

"The continuous communications contacts, the full-time data retrieval, and the very high data rate capacity which TDRSS affords, have introduced a new dimension into the mission planning and conduct of complex space missions."

Robert O. Aller
NASA Associate Administrator
For Space Tracking and Data Systems
in a speech at 36th Meeting of
International Astronautical Federation,
October 1985, Stockholm, Sweden

THE HUBBLE SPACE TELESCOPE, left, is expected to become one of the heaviest users of the TDRSS satellites for transmission of images of astronomical objects and other communications of its scientific findings.

Landsat 4, right, is one of the biggest TDRSS users for applications. The Landsat's "Thematic Mapper" and its other observation instruments require voluminous communications channels to Earth.

Accordingly, the demand for Earth-to-orbit and orbit-to-Earth communication channels is multiplying rapidly. High-volume, continuous communications channels are needed by Shuttle crews, research scientists, users of weather and Earth resources spacecraft, and even by entrepreneurs looking into incipient investment opportunities for commercial and industrial high-technology ventures in space. The new *TDRSS* is designed to fill these growing communications needs and wants.

Shuttle crews, who are the primary users of the new *Space Network*, require nearly continuous voice, television, data, and telemetry channels to and from Mission Control. They need to relay current research and operational information and to obtain expert input for their work from specialists on the ground.

That work nowadays involves complicated scientific experiments with sophisticated on-board instruments, the launching from the Shuttle's cargo bay of costly commercial and scientific spacecraft, and the retrieval and in-orbit repairs of malfunctioning spacecraft. As the costs and complexity of automated spacecraft continue to rise, in-orbit servicing and maintenance of these craft by Shuttle crews becomes more and more economically attractive.

Shuttle crews working in two shifts of 12 hours each need nearly around-the-clock communciations channels. These needs and wants are bound to multiply when Shuttle crews begin to assemble in orbit the planned U.S. Space Station, and when that Space Station begins its own operations in the 1990s. The station will be a permanent, continuously inhabited research and work facility requiring nearly continuous voice, television, data, and telemetry channels to Earth.

Astronauts, scientists, engineers, and other specialists will be living and working in the Space Station for periods of up to several months until new crews replace them. The regions in near-Earth orbit will never again be uninhabited at any time.

The Space Station is expected to become a hub for scientific, industrial, and commercial research and, eventually, a manufacturing facility for products with qualities that can be achieved only in the prolonged low gravity or high vacuum of space.

Materials processing experiments, which began in early U.S. manned space flights in the 1960s and 1970s, have been expanded on Shuttle flights. Early candidates for manufacturing in orbit are medicines and pharmaceutical products on which many people may come to depend for their well-being; crystals and other electronic components for faster and "smarter" computers than any now available; and alloys with unprecedented strength and conductivity.

NASA's Office of Commercial Programs was established in 1984 to encourage and help businessmen invest in and establish commercial enterprises in space. President Reagan has predicted that "before the end of this century, many billions of dollars of commercial activity will be taking place in and because of space."

Studies indicate that some 500 materials may be advantageously produced in space. Among these are glasses with until now unachievable optical qualities, lighter and stronger alloys from metals which cannot be uniformly mixed on Earth because of their widely varying weights, and biological substances which cannot be separated within the pull of Earth's gravity.

As raw materials and manufacturing equipment are transported to the Space Station and finished products are returned to Earth, and as production and research crews are rotated, the demands for voice and data communications channels are bound to intensify.

Similarly, the demand for communications by unmanned applications spacecraft is growing.

For example, two Earth resources observation satellites, Landsat 4 and 5, are equipped with "Thematic Mappers," powerful remote sensing instruments which gather valuable observations about conditions on the Earth. These instruments required high-rate communications channels to relay their huge volumes of findings. Until the first *TDRSS* satellite began its operations, the Thematic Mappers' observations could not be transmitted to Earth because of the limited ground station capabilities.

The single *TDRSS* satellite in orbit since 1983 has already proven it can provide the stringent communciations needs of space recovery operations. The satellite's ability to communicate with the Shuttle for almost half of each orbit greatly aided Mission Control in monitoring the successful in-orbit repairs by astronauts of the malfunctioning Solar Maximum Mission scientific spacecraft in 1984. Similarly, the *TDRSS* played a crucial role in the retrieval of two communications satellites in improper orbits in that same year, and in the repair of the failing Syncom IV-3 in 1985.

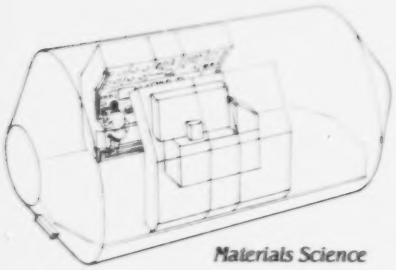
Experience over a quarter of a century of manned space operations has shown that lengthy dialogue between Mission Control and spacecraft crews can become essential for survival in emergencies. Life-threatening damage to the Apollo 13 craft from an on-board explosion during a flight to the Moon in 1970 was overcome mainly because experts on the ground were able to discuss at length with the crew how best to compensate for the impaired equipment.

One of the chief science users of the new *Space Network* will be the Hubble Space Telescope. The new telescope's optics will see objects 50 times fainter than today's best instruments can discern. It will look back in time, viewing radiations from the edge of the universe that have been traveling at the speed of light for billions of years.

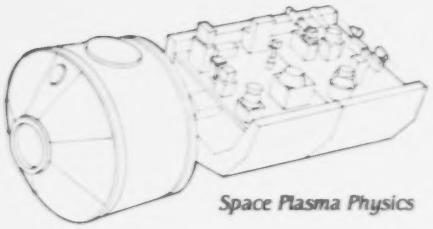
From these observations researchers expect to learn much about still mysterious celestial entities and processes taking place at nearly incredible distances and about the evolution and possible future of the universe. About 30 minutes of extensive transmissions through the *TDRSS* satellites are expected to be needed on each of the telescope's orbits. These transmissions are needed for operating the telescope's instruments, for tracking the craft, and for relaying to Earth its large quantities of measurements and images gathered on each orbit.

These transmissions will be channeled to the Space Telescope Science Institute Facility at the Johns Hopkins University, Baltimore, Maryland. There, all of the telescope's observations will be analyzed and archived for continuing studies by scientists.

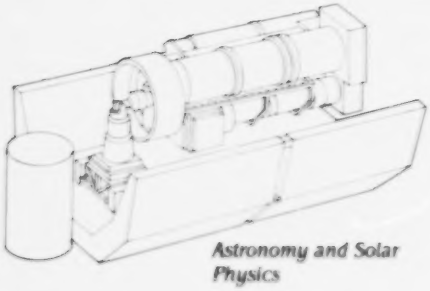
SPACELAB, the orbital European-built research module that fits into the Shuttle cargo bay, generates colossal quantities of scientific data, which need to be quickly transmitted to Earth. Spacelab has been one of the heaviest users of TDRSS.



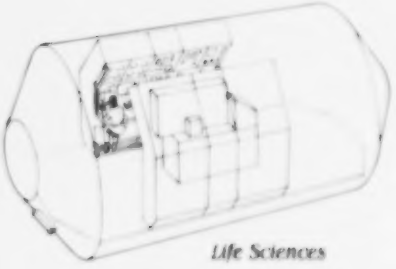
Materials Science



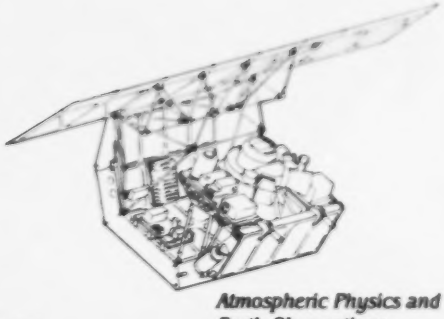
Space Plasma Physics



Astronomy and Solar Physics



Life Sciences



Atmospheric Physics and Earth Observations

Other major science users of the *TDRSS* are expected to be a variety of low-orbiting spacecraft studying physical and chemical processes of the upper atmosphere, measuring Earth's gravitational and magnetic properties, and examining and mapping aspects of the galaxy and the distant universe.

Among these is the "Solar Mesosphere Explorer," a spacecraft instrumented for examining certain constituents of the upper atmosphere such as ozone and nitric acid concentrations. The craft has been communicating up to now through the Earth stations of the current Spaceflight Tracking and Data Network (STDN), but is expected to change to the new *Space Network*.

Also expected to be served by the new *Network* are the "Cosmic Background Explorer" through which scientists are gradually assembling a full-sky map of diffuse cosmic background radiations; the "Gamma Ray Astronomy Observatory," which is examining the structure of our galaxy; the "Earth Radiation Budget Experiment," measuring the absorption and reflection of solar radiations by the Earth; the "Geopotential Research Mission," accumulating gravity and magnetic Earth data; and the "Upper Atmosphere Research Satellite."

SHUTTLE CARGOES are usually extensive users of the TDRSS satellites. Scientific instruments in the Shuttle's cargo bay require communications for monitoring and control from Earth and for quick analysis of instrument outputs so that instrument adjustments can be made. Shown here are various configurations of Spacelab scientific and applications research payloads.

Eventually most U.S. spacecraft in low-Earth orbits are expected to be serviced by the new *Network*, substantially enhancing their performance through more flexible operations and high data rate capacity. In these and other ways the *Space Network* is expected to have profound impact on the future of the U.S. space program.

On the Earth, the growth in the quality and quantity of communications facilities has changed our way of life. With the nearly universal availability of telephones, radio, and television, which has come about in this century, instantaneous access to news, information, entertainment, and to person-to-person electronic communication is taken for granted.

The communications revolution of the last several decades has brought people on the Earth closer, shrinking or wiping out many of the once formidable barriers between them. Modern communication has had significant impact on commerce, industry, education, medicine, and almost every other human activity.

The new *Space Network* is an extension of that communications revolution into space. The *Network* will open unprecedented new possibilities and opportunities for making use of the unique attributes of space for science, industry, and numerous other valuable purposes.

The end of total dependence on Earth-based stations for space communications closes an important chapter in the history of the U.S. space program. The *Space Network* is designed for service now and in the future. A fully functioning *Space Network* is the beginning of what might be called the Space Communications Age.

The *TDRSS* operates at both S-band (2025-2300 mHz) and at Ku-Band (13700-5115 mHz).

The Multiple Access Service (MA) operates in the S-band communications frequency and uses a fixed antenna on the *TDRSS* satellite to communicate with many spacecraft at the same time. This service is designed for low-rate, long-duration users. Precise location of the spacecraft can be determined, but is not required for use of the MA services. The amount of data (band-width) which can be relayed to the Earth is limited to 50 kilobits per second.

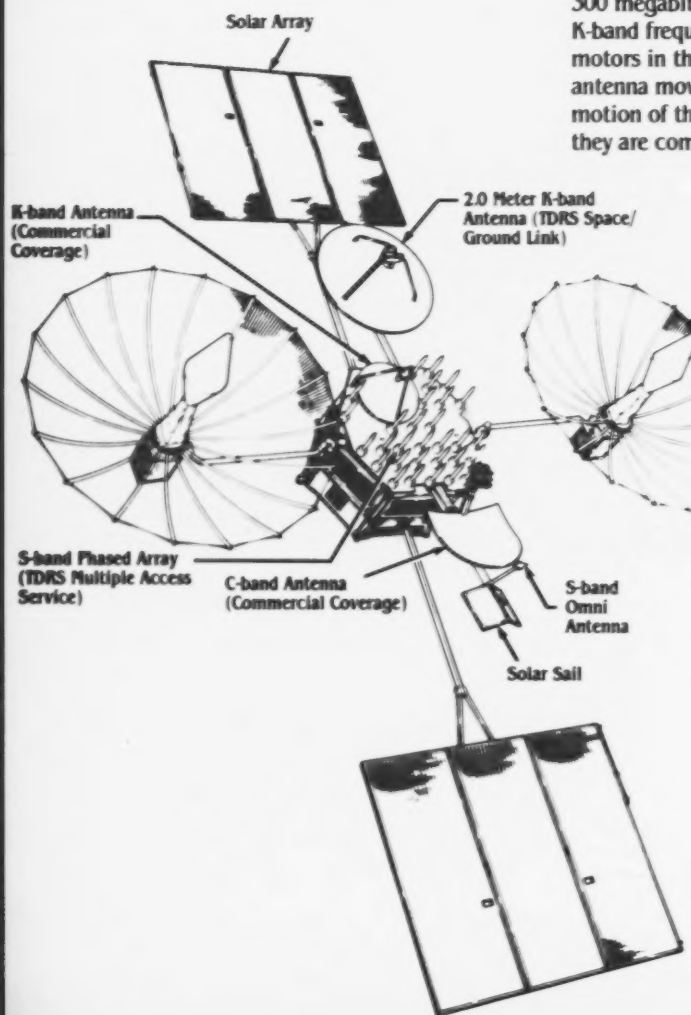
The *Single Access Service (SA)* is divided into two frequency bands, the S-band (SSA) and the K-band (KSA), and uses very sensitive steerable 4.9-meter (16.3-foot) parabolic dish antennas to communicate with one spacecraft at a time. Each *TDRSS* satellite has two such antennas. The SSA and KSA services are available simultaneously. The SA service is designed for spacecraft which require large quantities of data to be relayed.

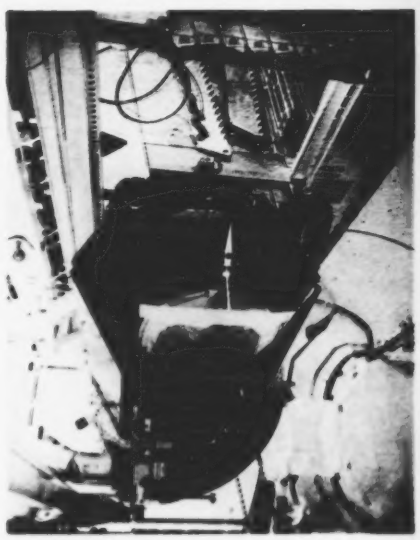
Communication through these antennas requires precise information about the location of a spacecraft so as to point the steerable satellite antenna to that spacecraft. Transmissions up to 6 megabits per second can be made at the S-band frequencies and up to 300 megabits per second in the K-band frequencies. Stepping motors in the arm and base of each antenna move them to follow the motion of the spacecraft with which they are communicating.

Each antenna responds independently to steering commands from the *TDRSS* White Sands Ground Terminal. To reach the maximum data relay capacity a spacecraft also needs to be equipped with a steerable high-gain antenna.

(For example, Landsat 5 is equipped with 1.8-meter parabolic antenna and transmits its Thematic Mapper data to *TDRSS* at 84 megabits per second. The Space Telescope will have a 1.3-meter antenna with a data rate of 1.024 megabits per second on the S-band.)

The space-to-ground link (SGL) antenna is a gimballed 2-meter (6.6-foot) parabolic reflector on the end of a fixed arm. It provides high-power K-band SGL communications between the *TDRSS* satellite and the White Sands Ground Terminal. All data to and from spacecraft serviced by the *TDRSS* flows through this antenna.


Solar Array
K-band Antenna (Commercial Coverage)
2.0 Meter K-band Antenna (TDRS Space/ Ground Link)
4.9 Meter Antenna (2) (TDRS K/S band Single Access Service and Commercial K-band Spot Beam)
S-band Phased Array (TDRS Multiple Access Service)
C-band Antenna (Commercial Coverage)
S-band Omni Antenna
Solar Sail



DISH ANTENNAS of the TDRSS satellite, seen from above, look like two long folded umbrellas as technicians inspect the hinges and deployment mechanisms prior to loading the satellite into the Shuttle cargo bay for launch.

The White Sands Ground Terminal provides the following equipment and services:

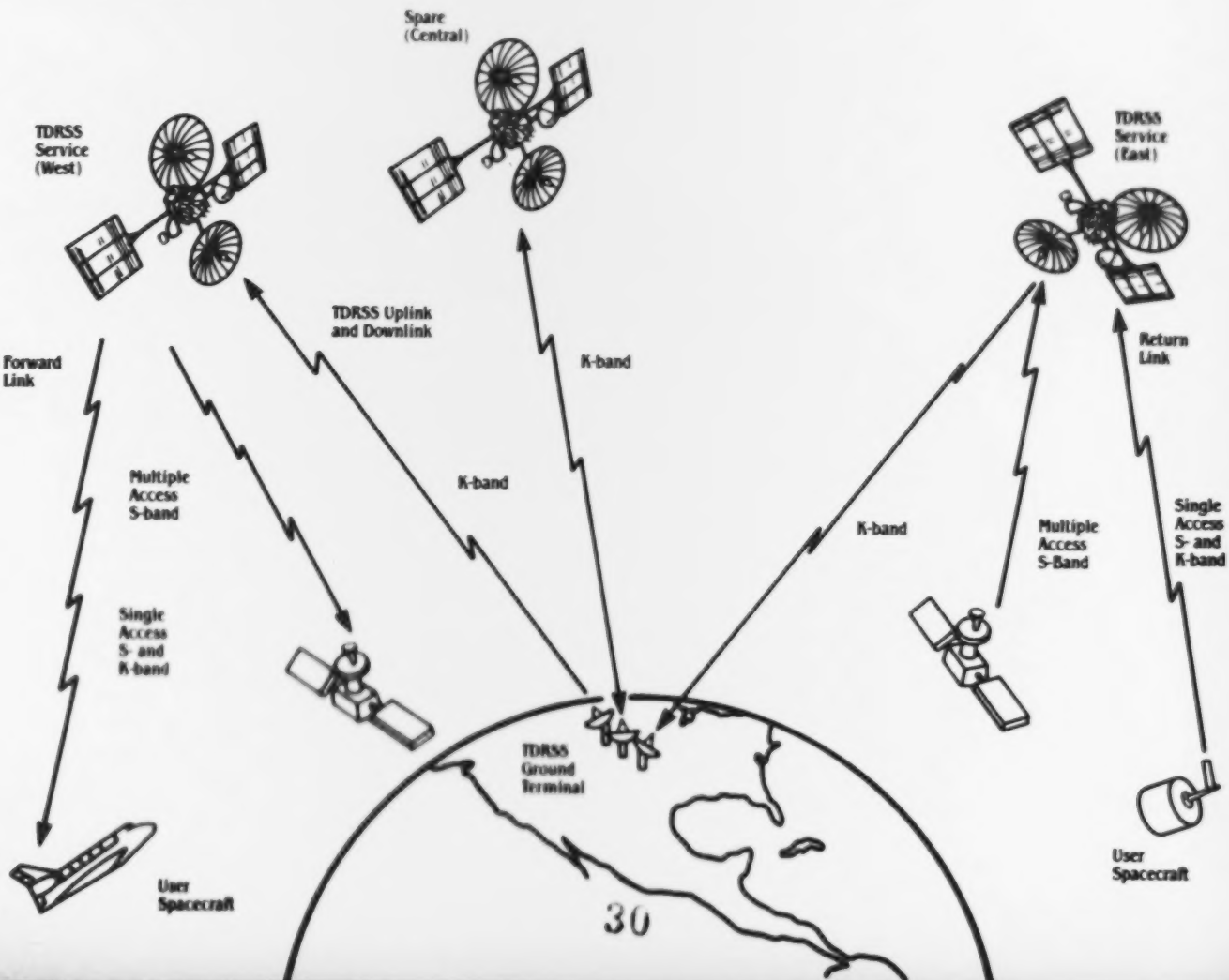
- Three 18-meter (60-foot) K-band antennas serving the space-to-ground link for the two active *TDRSS* satellites and the backup satellite. An S-band telemetry and command antenna for communications with the spare satellite. Several other antennas for simulation and calibration of spacecraft to test and adjust their compatibility with the *TDRSS* network.
- Central radio frequency receivers, transmitters and associated RF signal processing equipment necessary to receive and process data streams from spacecraft and to prepare forward signals for transmission to these spacecraft.

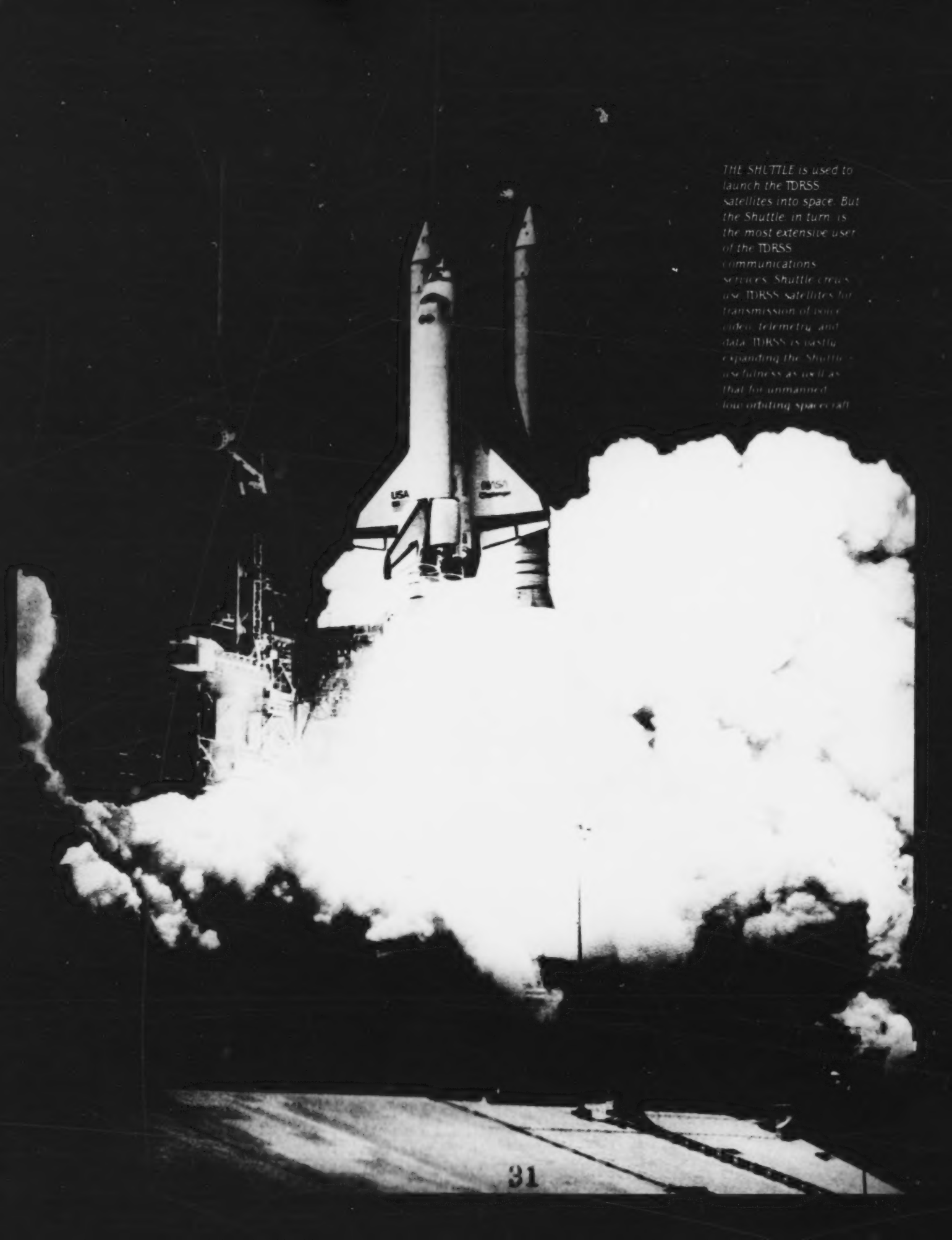
Equipment is maintained to separate up to 20 signals from the MA phased array outputs and to properly prepare MA forward commands for transmission to specific spacecraft communicating through the MA system.

- The software to determine range and range rate tracking data measurements from spacecraft communications signals. These measurements are required for the determination of spacecraft locations and orbit parameters. The information is used to steer the *TDRSS* satellite's SA antennas for communication with these spacecraft.
- Computer software to receive service requests from NASA and to convert these into equipment allocations and configurations through which these requests can be executed.
- Computer capability to monitor *TDRSS* satellite operations and to warn system controllers when action may be necessary.

Instruments for these functions are housed in the equipment and office buildings at White Sands, New Mexico.

For additional information contact:
National Aeronautics and Space Administration
Washington, D.C. 20546





THE SHUTTLE is used to launch the TDRSS satellites into space. But the Shuttle, in turn, is the most extensive user of the TDRSS communications services. Shuttle crews use TDRSS satellites for transmission of voice, video, telemetry, and data. TDRSS is vastly expanding the Shuttle's usefulness as well as that for unmanned low-orbiting spacecraft.

Most treasures which have come from space to Earth so far have been in the form of information and observations. These are leading to knowledge and understanding perhaps more precious than material returns. The three TDRSS satellites and their associated ground facilities substantially increase the quantities of information and observations which can be transmitted to the Earth.

NASA